Precipitation Metrics and the Energy-Food-Water Nexus: Challenges and Opportunities

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2016 PMM Science Team Meeting

Motivation

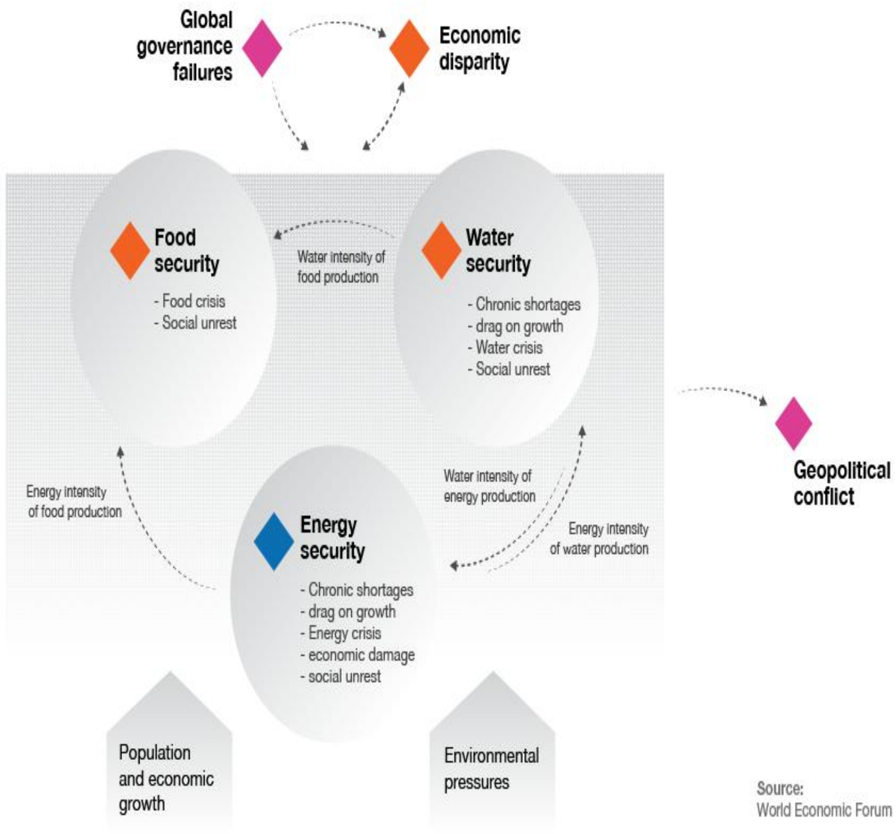
Global projections by 2030

•50% increase in food demand
•30% increase in water demand,
•40% increase in energy demand.

Key Drivers

•Urbanization
•Population increases

Villamayor-Tomas et al. (2015): many frameworks have been used to study ***the* Energy-Water-Food-Network (*EWFN)*,** *however, little attention to the hydroclimate implications and interactions (mostly* greenhouse gas emission, landuse, resource management efficiency, or societal facets).



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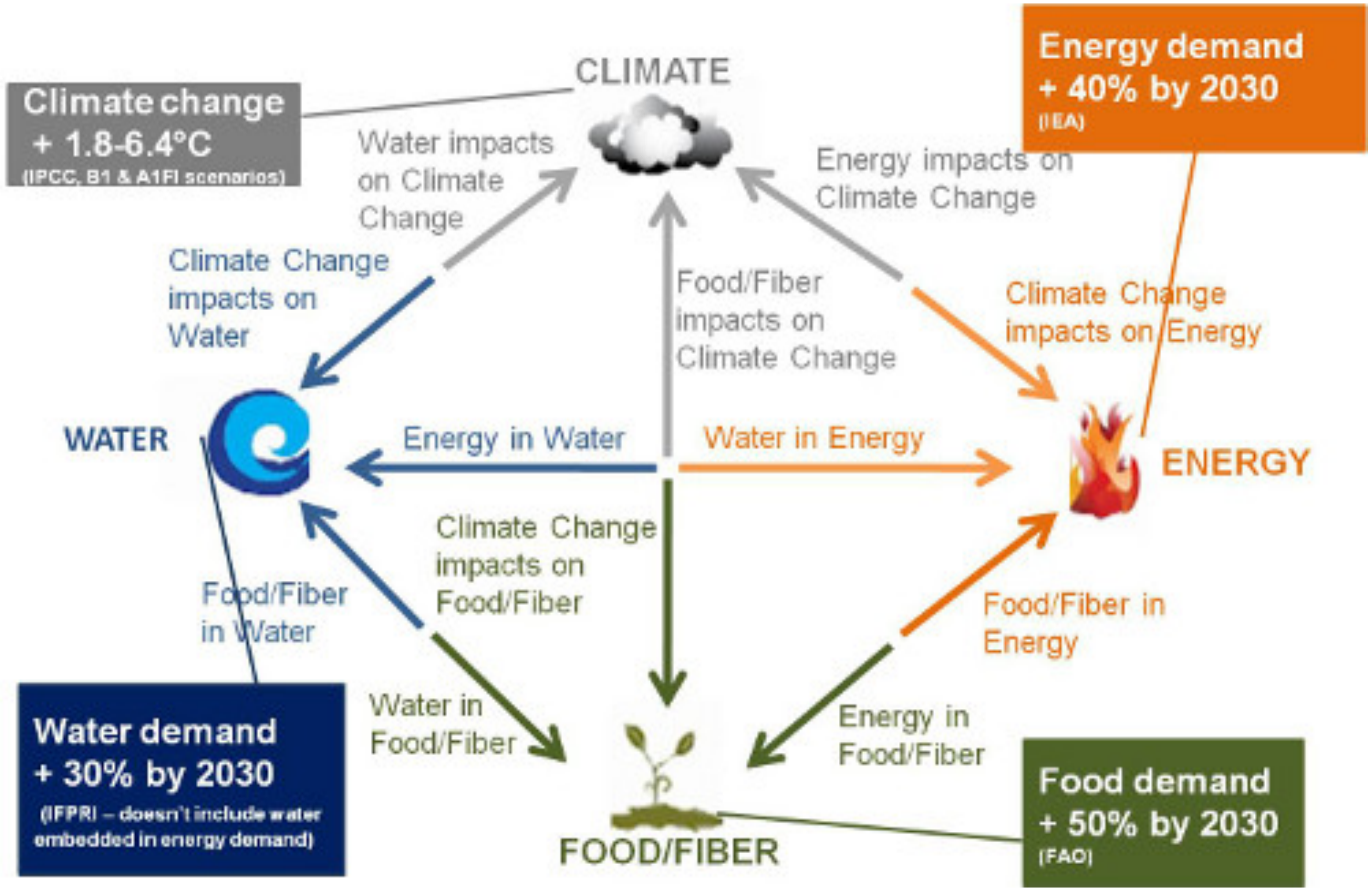
Hydroclimate and the EWF Nexus



Our **motivation** is to describe emerging efforts to link satellite based precipitation data and other NASA data to support the EWF nexus related to urban transitions and interconnections to agriculture.

Research Objectives

- *Can precipitation metrics such as precipitation per capita (PPC, precipitation per individual (PPI), or precipitation per acre (PPA) be quantified using PMM datasets?*

- *If so, can spatio-temporal trends in the metric be useful in the assessment of the EWFN capacities and vulnerabilities?*

- *How will addition of urban agriculture and irrigation affect urban microclimate and regional precipitation patterns?*

- *How vulnerable is urban agriculture to hydroclimate variability and extreme events?*

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NASA Programmatic Relevance

PMM RFP

•*Development of metrics and methodologies for assessing satellite precipitation products in hydrological applications…….*

•*Development of other precipitation related applications in areas as described at http://pmm.nasa.gov/applications* ”

- Our work particularly aligns with applications related to agriculture and freshwater availability and echoes needs discussed in the recent 2015 GPM Applications Workshop held in Maryland.
- Further, *our team already* ***has an established partnership with USAID****, which allows the research to find societal applications rather efficiently*

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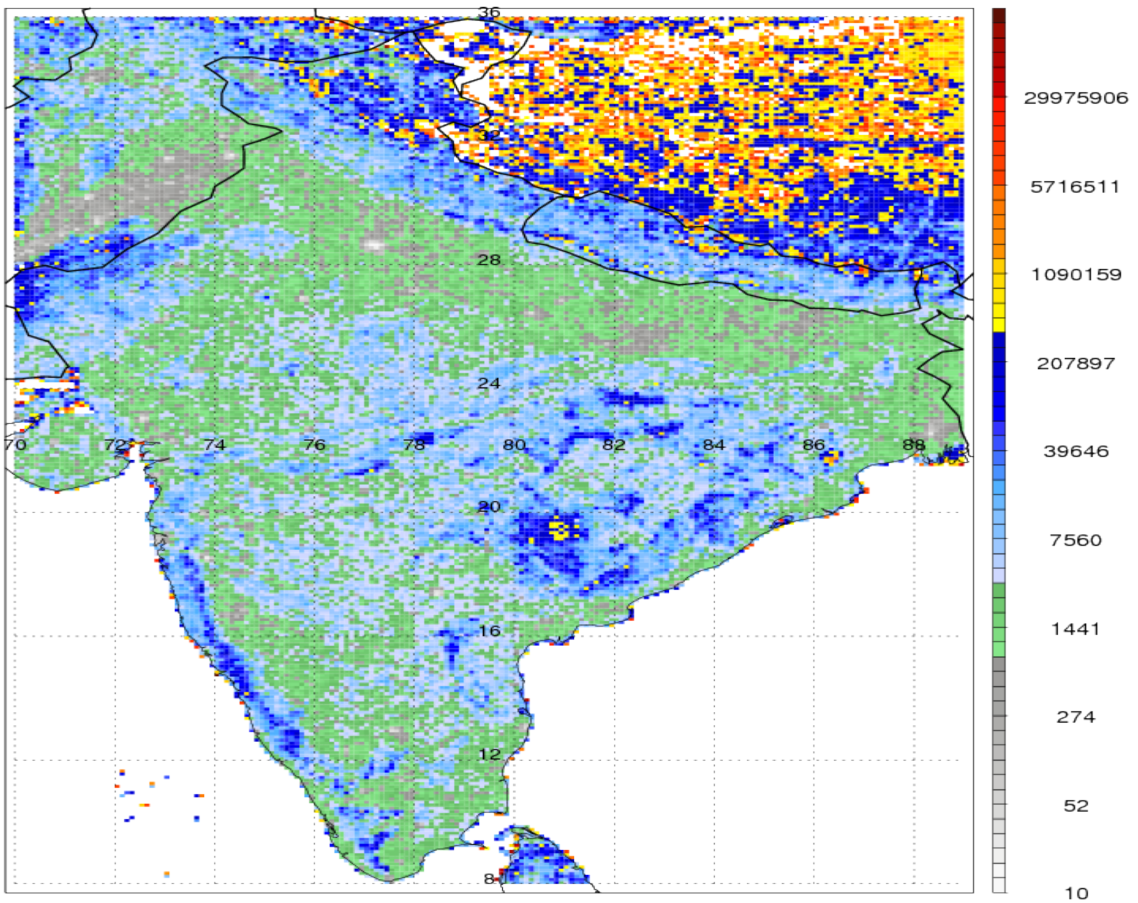
Research Theme 1: Precipitation Metrics

- Precipitation per person (ton/year/person in 0.1 deg x 0.1 deg space) over India (courtesy C. Liu)



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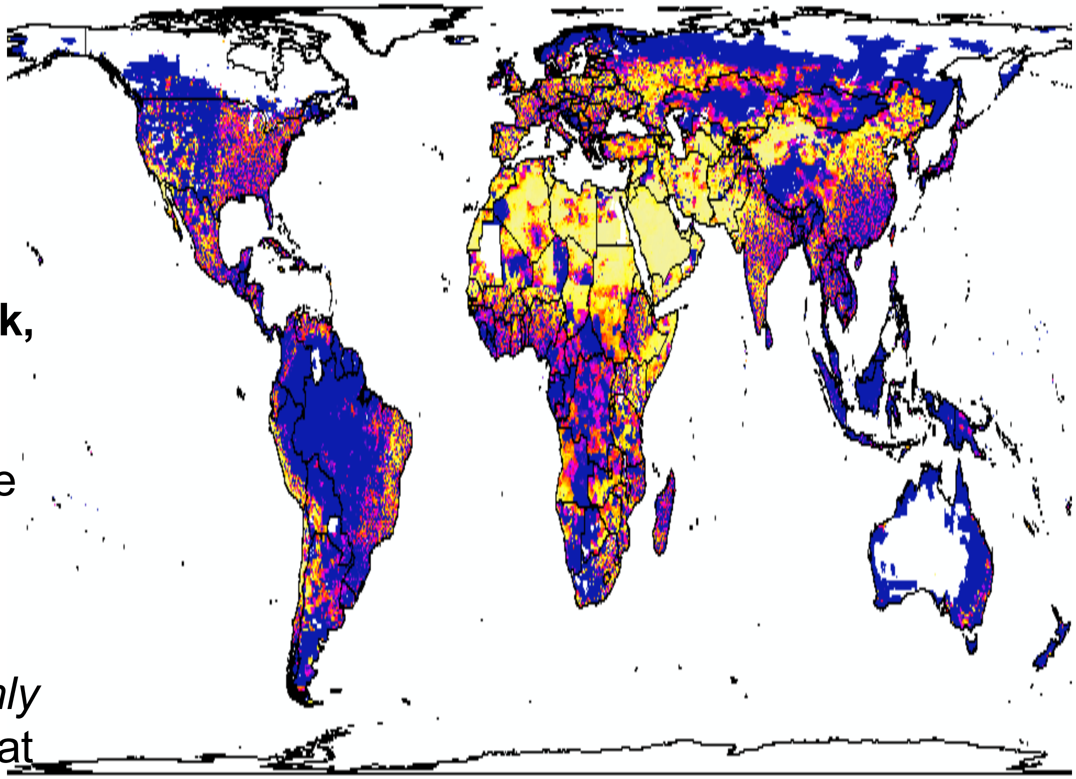
Goal is to Refine and Develop These Metrics. We Are Still in Exploratory Mode

- University of Georgia using the Population Count Grid Future Estimates V3. FAO, CIAT, and CIESIN - Columbia University

- **12 months of GPM data (IMERG),** and converted rates to totals and computed total precipitation for the period March 2014 to February 2015 (**Purple and Pink, high precipitation per population**).

- Precipitation grid resampled to match the population grid (2.5' -about 4km)

- The precipitation/population map is certainly driven by population, *but not only by population*. If precipitation is somewhat homogeneously distributed over the region, population will define where boundaries will happen. If population is homogeneously distributed, precipitation defines the boundaries.



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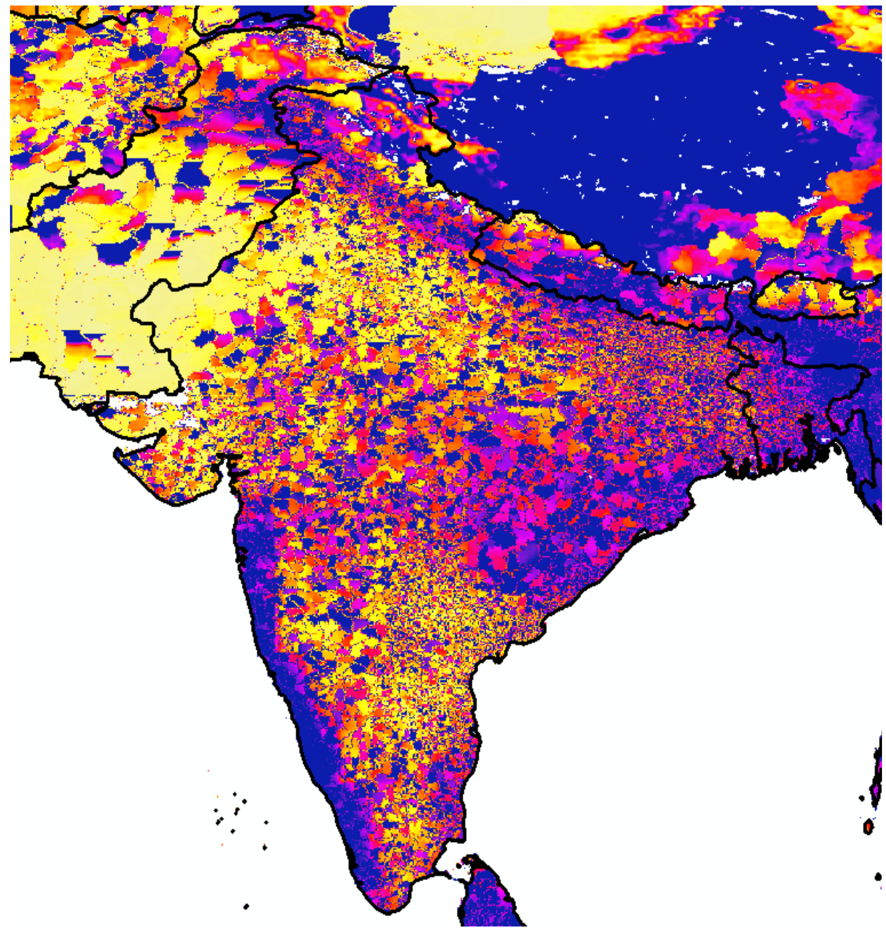
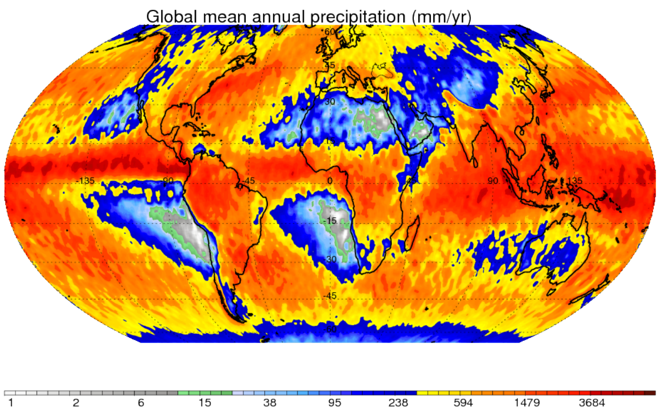
Closer Look……

- India is a great example of precipitation and population individually driving the results at different parts of the country.

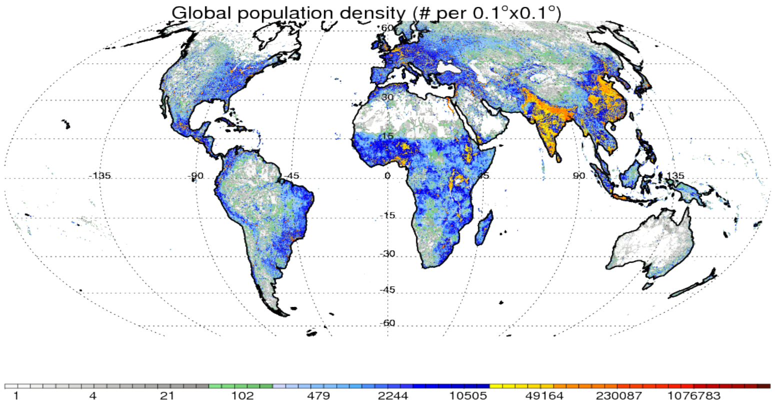


Preliminary Results (Courtesy C. Liu/TAMU-CC)

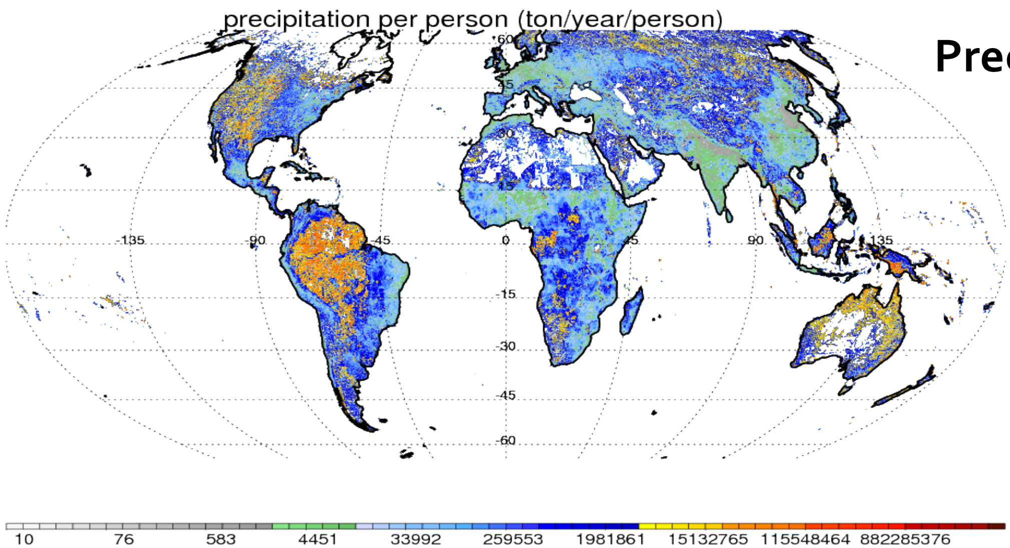
Two year mean precipitation rate from GPM Ku radar estimates



Global Population Density



Precipitation Per Person



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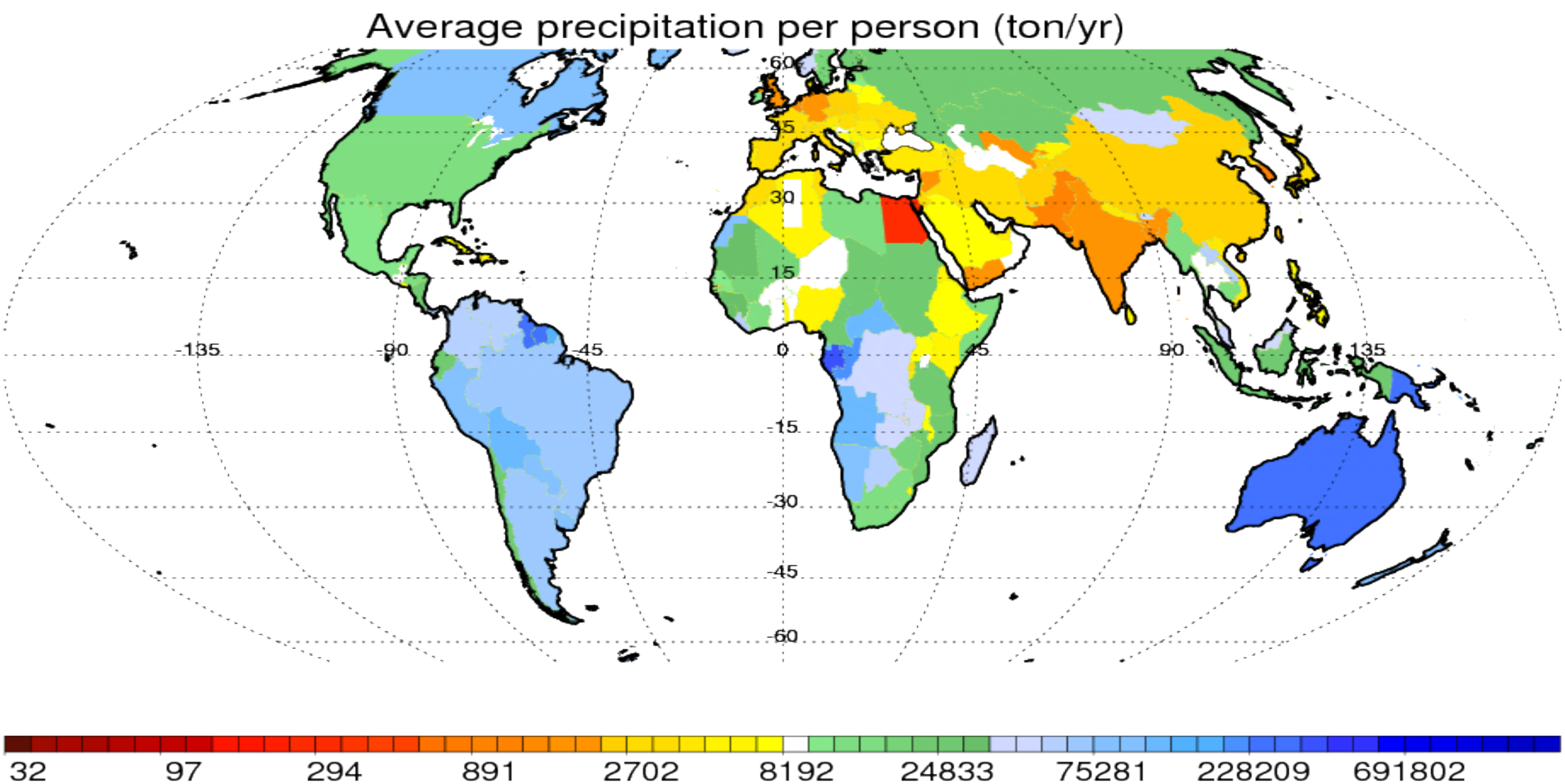
Country Mean



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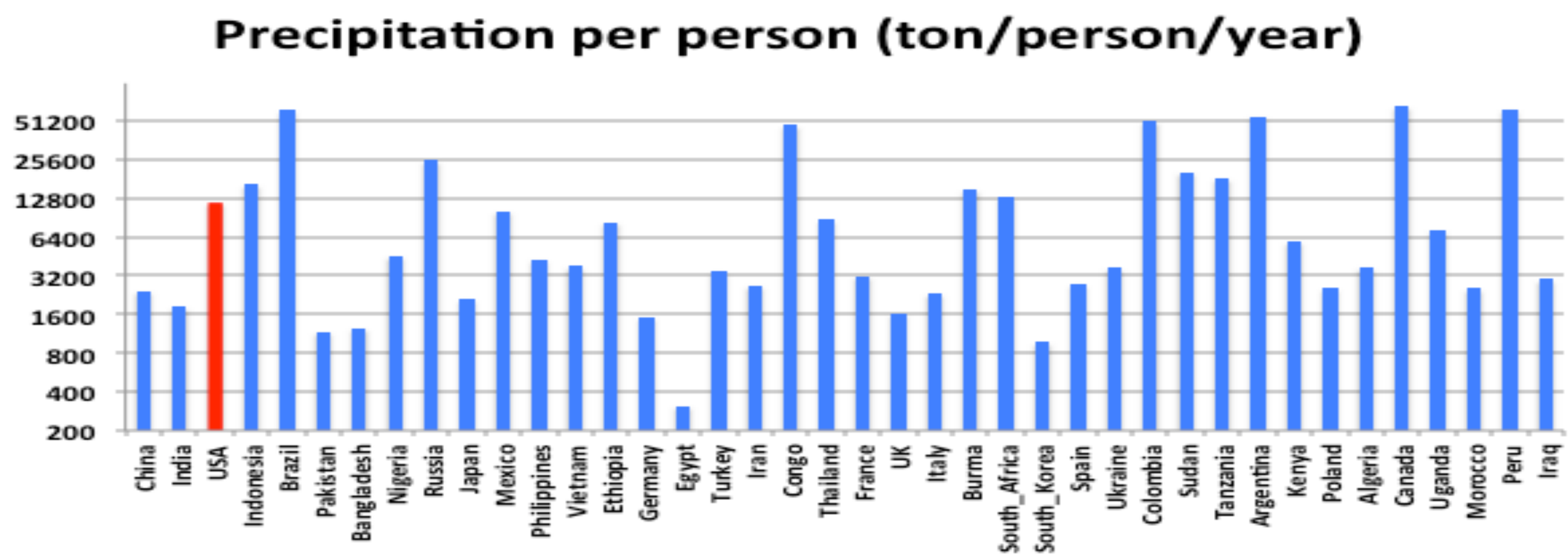
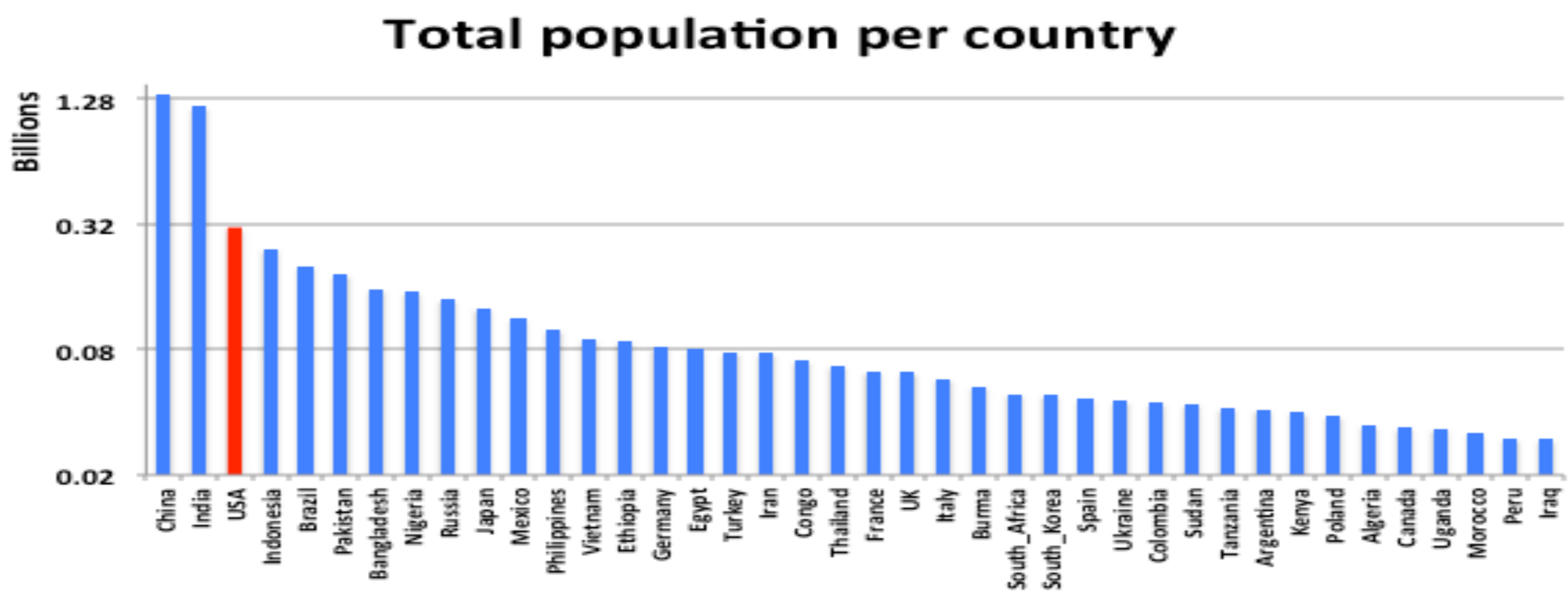
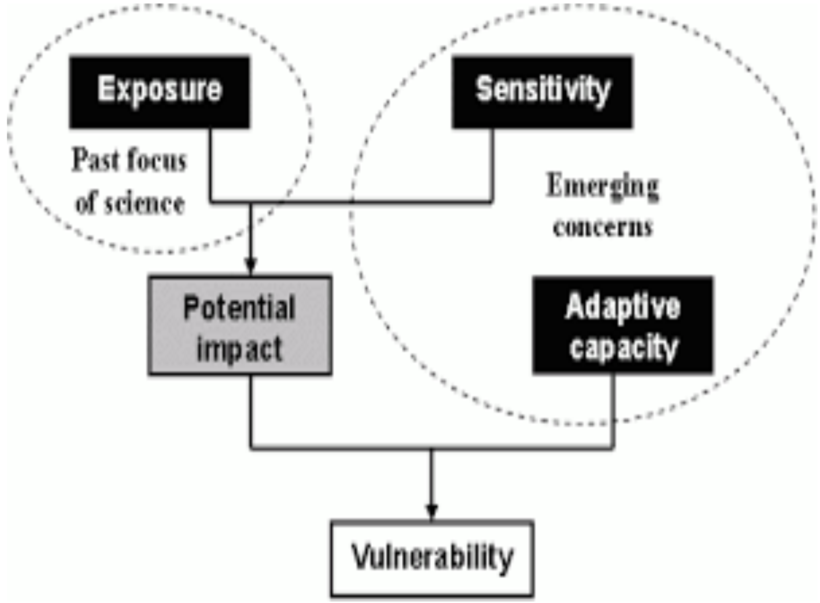

Precipitation per person (ton/person/year)
51200
25600
12800
6400
3200
1600
800
400
200
China
India
USA
Indonesia
Brazil
Pakistan
Bangladesh
Nigeria
Russia
Japan
Mexico
Philippines
Vietnam
Ethiopia
Germany
Egypt
Turkey
Iran
Congo
Thailand
France
UK
Italy
Burma
South_Africa
South_Korea
Spain
Ukraine
Colombia
Sudan
Tanzania
Argentina
Kenya
Poland
Algeria
Canada
Uganda
Morocco
Peru
Iraq


Total population per country
Billions
1.28
0.32
0.08
0.02
China
India
USA
Indonesia
Brazil
Pakistan
Bangladesh
Nigeria
Russia
Japan
Mexico
Philippines
Vietnam
Ethiopia
Germany
Egypt
Turkey
Iran
Congo
Thailand
France
UK
Italy
Burma
South_Africa
South_Korea
Spain
Ukraine
Colombia
Sudan
Tanzania
Argentina
Kenya
Poland
Algeria
Canada
Uganda
Morocco
Peru
Iraq

Research Theme 2: Ecosystem Services and Water

- *What is the potential for precipitation-driven food production and other ecosystem services in cities and how do they vary spatially and temporally globally?*

- *How can precipitation metrics be used to assess water vulnerability*



Concepts represented in Stout et al. 2015, Shepherd and KC 2015, KC et al. 2015

Urban areas, rainfall, and water

- Water from 1-inch of rainfall (from http://www.mrsoshouse.com/water/precippop.html and data via USGS)

City	Area* (acres)	Amounts of Water (billions of gallons)
Atlanta, Georgia	86,976	2.36
Boston, Massachusetts	29,440	0.80
Chicago, Illinois	29,440	3.85
Denver, Colorado	43,328	1.18
Detroit, Michigan	88,320	2.39
Los Angeles, California	291,264	7.91

An Example:

Atlanta receives 106 billion gallons of water (via rainfall) in an average year. If the per capita water use is 40,150 gallons per year, it is clear that a large percentage of the population could be sustained by this stored rainfall (assuming no evaporation loss).

BUT Residents of urban centers in less developed countries, which are often densely-packed (e.g., India) have limited access to potable water (Stout et al. 2015)

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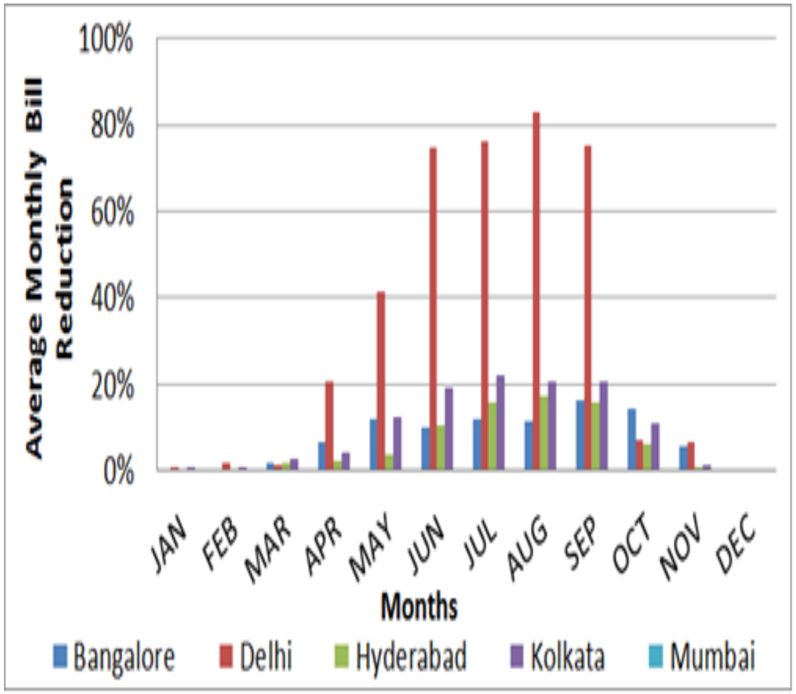
Applying Metrics to Ecosystem Services and Vulnerability

Urban rainwater harvesting (RWH), other concepts may be required.

- •PMM supported work, Stout et al. (2015)
  - 35 gallons of water per person were required in Dehli, Kolkata, or Bangalore and that RWH could provide roughly 20% of the indoor water demand.



- •RWH for 3 ecosystem services (water supplementation for indoor use, water supplementation for food production and groundwater recharge) also significantly reduced water bills

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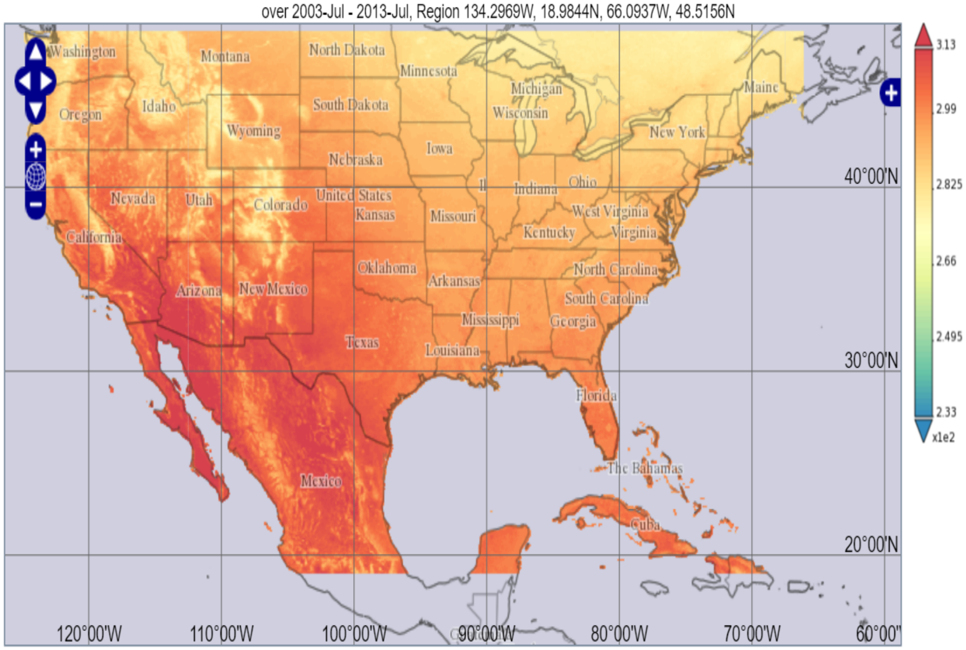
Research Theme 3: Urban-Agricultural Interactions

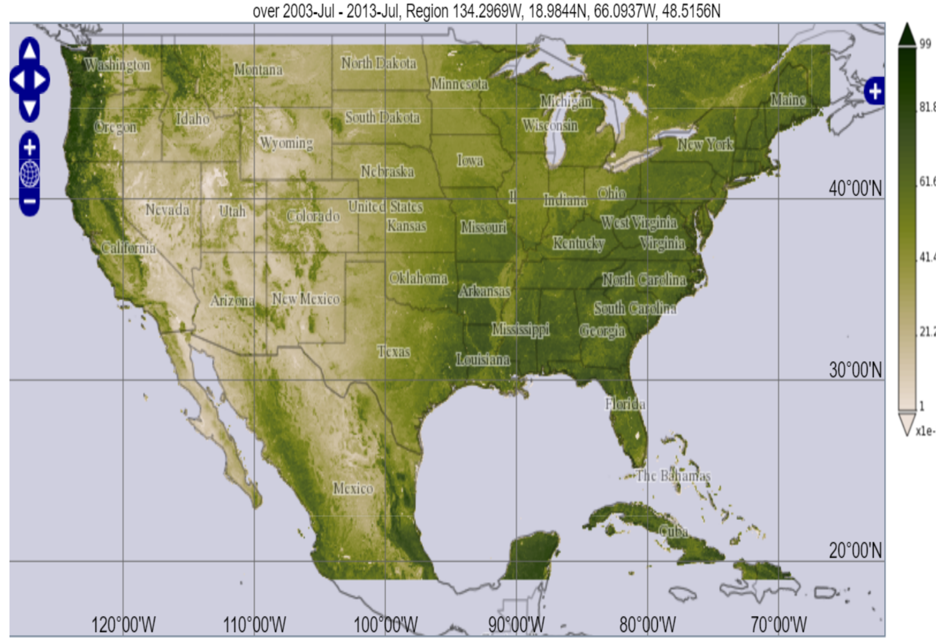
- *How do the urban-induced surface and boundary-layer meteorological changes affect farms near cities?*

- *How can the satellite observations and land surface models help capture the urban impact on agriculture?*

Time Averaged Map of Monthly daytime 3min CMG Land-surface Temperature monthly 5000 m [MODIS-Aqua MYD11C3 v005] K over 2003-Jul - 2013-Jul, Region 134.2969W, 18.9844N, 66.0937W, 48.5156N

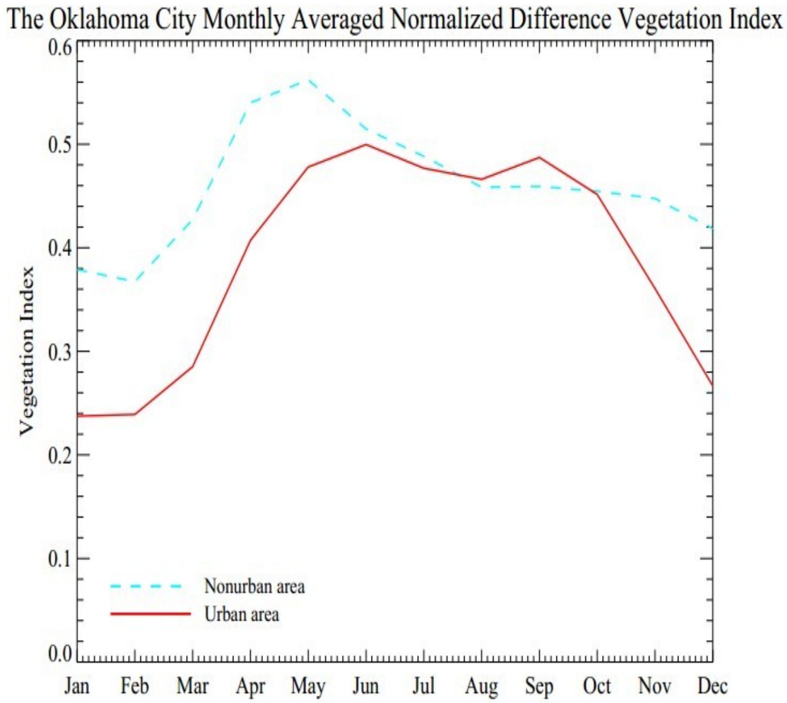


Time Averaged Map of CMG 0.05 Deg Monthly NDVI monthly 0.05 deg. [MODIS-Aqua MYD13C2 v005] NDVI over 2003-Jul - 2013-Jul, Region 134.2969W, 18.9844N, 66.0937W, 48.5156N



Preliminary goals

- The urban system results in significant changes to the agriculture-sensitive meteorological conditions including surface temperature, humidity, rainfall and aerosols (which reduce surface insolation).
- Net Primary Production (NPP) and Gross Primary Production (GPP) are closely related to surface temperature, rainfall and soil moisture.
- This project seeks to reveal the dynamics of GPP/NPP associated with surface temperature, rainfall, and related ecosystems variables and their responses to the nearby urban growth.



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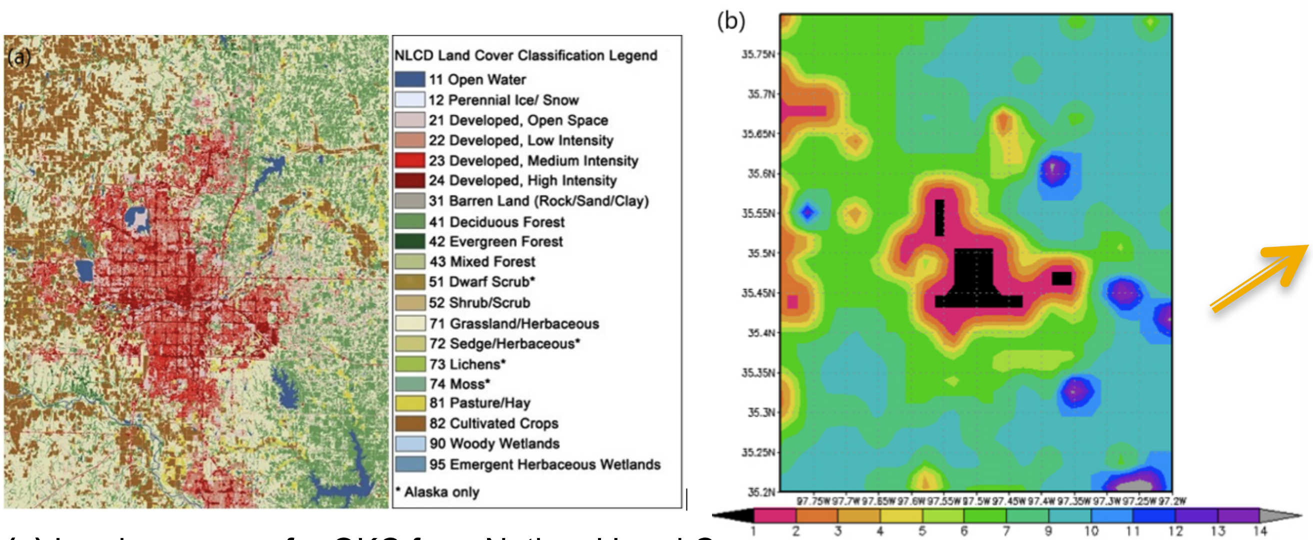
Forthcoming work

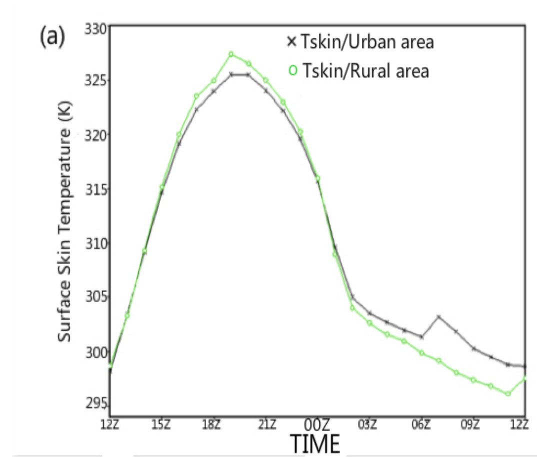
Future work for Theme 3

- Assess UHI and NPP and GPP relations

- Combine WRF simulations with satellite data to identify fundamental biogeochemical processes that affect NDVI and NPP.



(a) Land use maps for OKC from National Land Cover Database 2001 and (b) WRF/SLUCM simulation.



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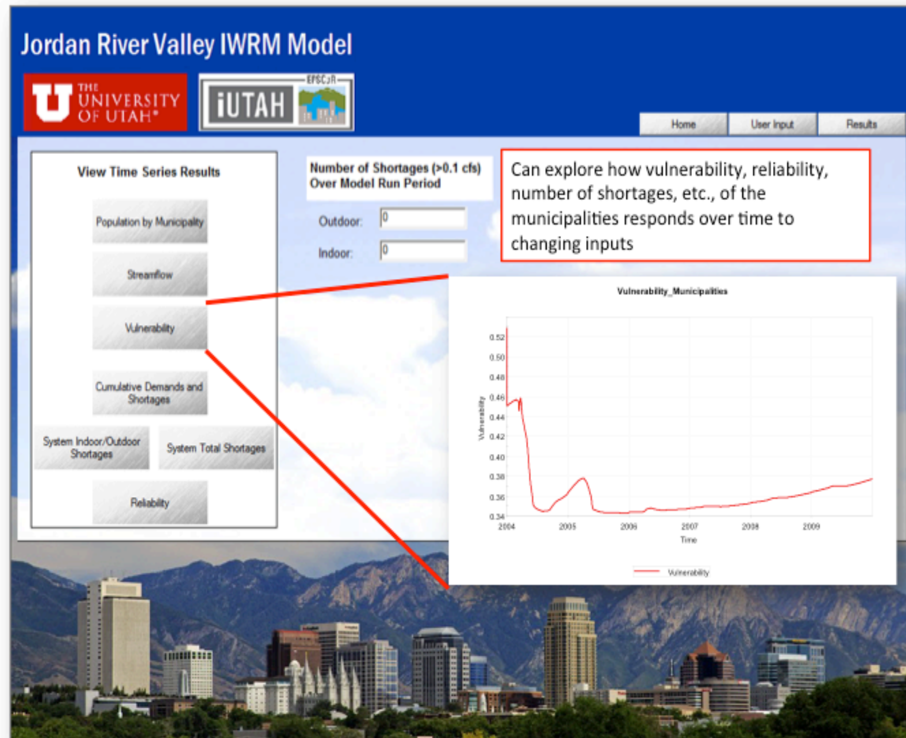
Wrap-up

- Shepherd et al. (2016) has been published in IEEE Earthzine introducing the Precipitation Metrics Concept, http://earthzine.org/2016/05/31/satellite-precipitation-metrics-to-study-the-energy-water-food-nexus-within-the-backdrop-of-an-urbanized-globe/

- UGA PhD Student Ansley Long will focus on development and application of Precipitation Metrics in the context of water vulnerability in western U.S.

- Utah PI and Student plans to merge Precipitation Metrics to asses water vulnerability and to drive systems models (right) to study EWF Nexus implications of climate extremes in the western U and Pakistan (USAID collaborations)

- Maryland PI is conducting NPP and dynamical modeling analysis for western U.S. and central China to assess affects of greenness and food productivity



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